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APPENDIX H. Interim BMAR Cost Estimating Methods

Method 1 - This method of BMAR calculation has been developed and is being tested by NASA maintenance managers at Dryden Flight Research Center (DFRC). DFRC is using a statistical analysis of the condition code, estimated replacement costs for inventory items and detailed repair cost data from their CMMS.

The process involves selecting a representative (random) sample (based on the confidence level desired) of equipment items in each of the five standard condition codes and the appropriate repair or replacement cost for those items. The ratio of repair cost to replacement cost for each of the inventory items selected is calculated and averaged to determine a condition code factor (CCF) for each condition code. The CCF is then multiplied by the total replacement cost for all equipment items in that condition code. This product is then summed for all condition codes to produce a statistically generated total BMAR value based on the actual condition of the plant.

Actual requirements (and condition codes for all inventory items) were developed through a baseline condition assessment of all equipment items, facilities and their major components. These requirements are currently being expanded, validated and incorporated in the CMMS as part of the normally scheduled PM/PT&I inspection process. All requirements, including BMAR, are maintained in the CMMS. Actual requirements can be extracted electronically from the CMMS. Equipment requiring repair can be extracted from the CMMS in almost any terms desired, and criticality codes, historical trouble call information and cost data is also available in the CMMS for condition determination and analysis purposes. The statistical methods proposed, if used properly, will reduce objectivity concerns and produce a real-time BMAR calculation based on the current condition, current replacement costs and detailed repair costs.

This process is strictly condition-based, involves some limited life-cycle cost procedures, statistically develops BMAR based on real-time condition and costs and is developed from CMMS data. Each step is described below along with the potential impact on other Centers and Component facilities when the procedure is implemented NASA-wide.

Step 1 - Ensure inventory is accurate. Each Center should ensure that its inventory of physical plant facilities and equipment is accurate and is developed down to the component level. This is most important because this method develops the BMAR estimate based on a percentage of the plant Current Replacement Value (CRV). Most NASA Centers have either recently validated their inventories or are in the process of doing it now, and most have developed their inventories down to the component level. Following the initial inventory, it then should be updated continuously as facilities, systems and equipment are added and deleted. From a NASA-wide standpoint, this step will not require significant resources to accomplish.

Step 2 - Complete a baseline condition assessment. Each location should complete a baseline condition assessment. It is imperative that the condition of all the physical plant inventory items is known. Most NASA locations have completed a baseline condition assessment or are in the process of completing one at this time.

Following the initial baseline condition assessment, the condition of each facility, system and unit of equipment should be updated continuously based on day-to-day input from the maintenance technicians, Facility Managers, users and occupants. From a NASA-wide standpoint, this step will not require significant resources to accomplish.

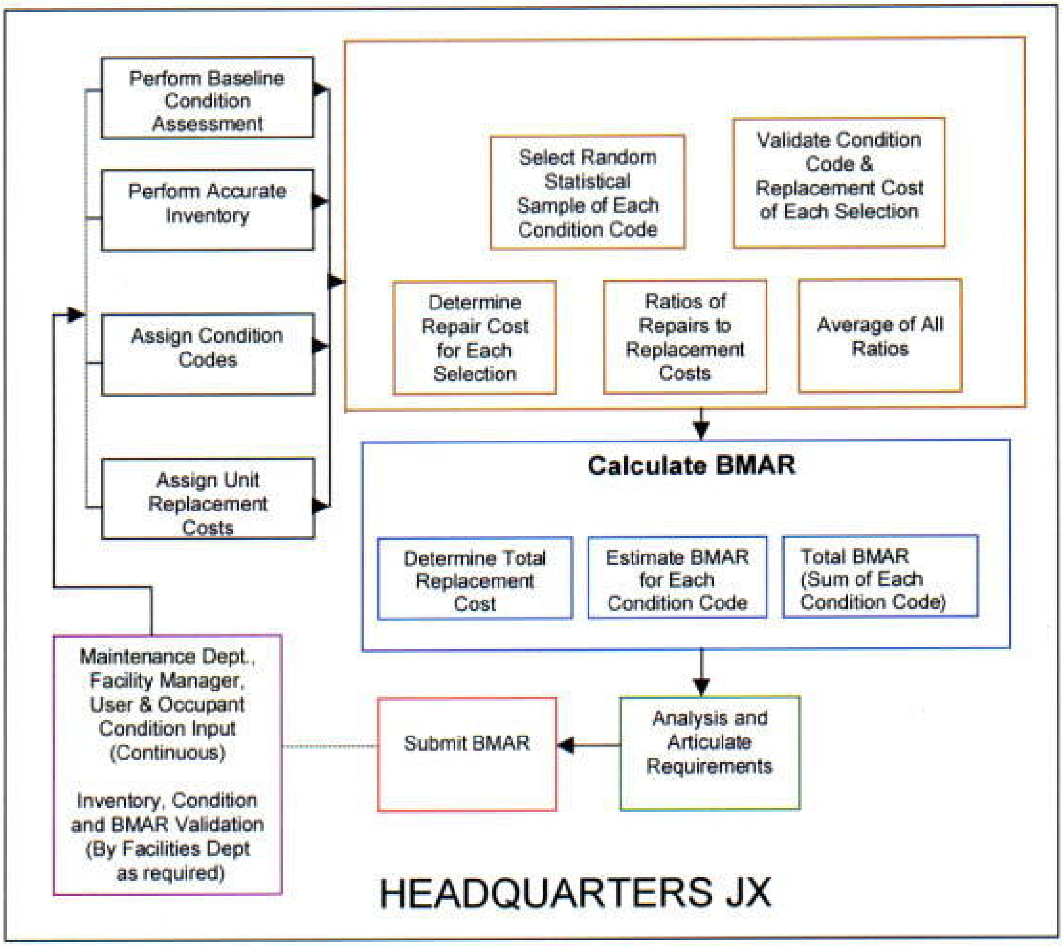

Figure H-1. Determining BMAR

Step 3 - Assign a condition code to all plant facilities and equipment. The condition assessment level code to be used should be simple, basic and easily understood. The condition codes proposed in Method 2 add excellent parameters that succinctly describe what the status of the item is and the scope of work required to bring it to acceptable maintenance standards. Much of this information can be provided from input by maintenance technicians, facility managers, users and occupants. It is important that it is simple, but with sufficient definition that everyone can at least attempt to apply it in a similar manner. Most NASA Centers either already have condition codes established, or are in the process of establishing them. Most condition data is or will be contained in facility condition assessment (FCA) databases, and some are in both the FCA and CMMS databases. It should not be a significant effort on the part of the NASA Centers and Component facilities to complete this action, and most are already in the process of completing it.

Step 4 - Assign Replacement costs. Current replacement costs for all inventory items must be established in the database to be used. Some NASA locations already have this information in their FCA or CMMS database. It is important that this data be developed from reputable cost reference data/guides. Most locations already use some form of the *R S Means Maintenance and Repair Cost Data*. It is recommended that the database that contains replacement cost data be set up to automatically update the costs to accommodate inflation. This action will be required at most NASA locations, but should not be too resource intensive to accomplish.

Step 5 - Calculate the Condition Code Factor. Calculation of the Condition Code Factor (CCF) will be peculiar to each Center depending on the condition of its facilities and equipment.

(1) Randomly select a statistically appropriate sample size (based on the confidence level desired) of inventory items for each condition code. An electronic or manual statistical sample selection table may be used to determine the appropriate and statistically accurate sample size. Websites are available on the internet where the required and statistically accurate sample size will be calculated at no cost by inputting basic information such as total population and desired degree of accuracy. On the web, search for *statistical sample size* and several on-line calculating

services (and software sales companies) will be identified.

(2) Determine the condition code and replacement cost for each of the items selected.

(3) Estimate the required repair costs for each of the inventory items selected in each condition code.

(4) Divide the required repair costs for each item selected by its corresponding replacement cost.

(5) Average the ratio of repair required to the current replacement cost for all items selected in each condition code. This is the CCF and there will be one for each condition code.

The most important part of this procedure is the true random selection of an appropriate sample size of inventory items within each condition code. This selection can be accomplished with the use of an electronic random number generator given that all the needed information is available in the database. Again, the randomness of inventory item selection and the determination of the proper sample size is key to the standardization and accuracy of the process. The determination of the appropriate sample size should be based on the level of confidence desired for the resultant BMAR approximation. The application of this calculation throughout NASA will not require a significant effort once the appropriate information is available in a database.

Step 6 - Calculate the BMAR approximation.

(1) Determine the total replacement cost for all inventory items included in each condition code.

(2) Multiply the CCF for each condition code by the total replacement cost of all inventory items included in each condition code. This is the estimated BMAR for each condition code.

(3) Sum the estimates of BMAR for each condition code. This is the statistically estimated BMAR for the entire physical plant for that location.

Step 7 - Use key management information for articulating requirements and analysis. If the BMAR calculation is accomplished from the CMMS database, additional information (criticality codes, failure data and historical cost and trouble call data) will also be available to further define and analyze the resultant BMAR calculation. Even if the calculation is done in another database, some of this analysis can be done manually, if necessary. Very few NASA locations have included their condition assessment information in their CMMS or linked the two databases. However, at most NASA locations, both databases are compatible and could be linked in the future if resources are available and it was deemed a cost-effective initiative.

Step 8 - Periodically validate condition codes. If the condition codes are periodically verified, especially as part of an already regularly scheduled maintenance inspection (PM/PT&I) or through input from the facility managers, building occupants or equipment users, the BMAR calculation almost becomes a real time estimate and follow-on (after the baseline) condition assessments are not required. This is done at some NASA locations currently. This procedure definitely depends on the size of the inventory and the ability to incorporate the condition code review without expending excessive resources. This procedure would not only determine a more accurate calculation, but could provide additional requirements information for the development of long-range plans. The more current the condition code, the better the assessment of current and future needs, and the more credible the calculation becomes. This is especially recommended for locations with small or medium size plant inventories.

Step 9 - Limit the inventory if it is cost-effective. A modification to this procedure to further reduce costs should be considered. Instead of including all inventory items in the calculation, it could be limited to the major facilities and their equipment, and the results extrapolated to determine the BMAR for the remaining assets. This would certainly make the process simpler for the larger locations with large plant inventories. This modification should be considered and possibly tested at all locations and applied where it will be cost-effective.

Method 2 - This methodology is described in Deferred Maintenance/Condition Assessment Discussion Paper, developed by Charles B. Pittinger, Jr., Facilities Engineering Division, Headquarters National Aeronautics and Space Administration (NASA), for presentation to the National Research Council.

This process of documenting deferred maintenance is designed to be a simplified approach based on creative thinking, which is minimally resource intensive and auditable in order to support Federal agencies annual financial reports. Its intended use is as a facility performance metric, which can be compared and trended against other commonly used facility metrics. It is a parametric estimate intended to be accurate enough for its intended purpose - a MACRO level metric.

The method assumes condition assessments are performed at the system level rather than the component level, simple condition levels are used, there are a limited number of systems to assess, and parametric estimating is used based on the CRV of the systems and the facility they support.

A simple 5-tiered condition code system is proposed which is assigned a representative repair cost factor based on a percentage of the facility CRV. The range of CRV by condition level is subject to further study.

Condition Assessment Level	Repair Cost

5 - New/Only PM required	5% of CRV
4 - Some repairs needed, system generally functional	20% of CRV
3 - Many repairs needed, limited functionality	50% of CRV
2 - May be functional, but obsolete or does not meet codes	100% of CRV
1 - Not operational, unsafe	100% of CRV

The major facility systems are identified and assigned representative cost factors based on their estimated percentage of the facility CRV. These factors can be adjusted for special facilities (wind tunnels, launch platforms, etc.). The range of CRV by major system is subject to further study.

Major system	% of Facility CRV
Architectural	5
Roof	10
Electrical	15
Plumbing	15
HVAC	25
Structural	30
	100
Site	100
Utility Systems - exterior	100

The procedure then determines the condition codes for the systems, site and utilities for a given facility, multiplies the appropriate repair cost factors and system cost factors for each and sums them for the facility (site and utilities separate). This total system factor is then multiplied by the facility CRV (same for site and utilities CRV's) and added to the site and utilities calculation to come up with an estimated value for the deferred maintenance for that facility.

The cost of gathering deferred maintenance data can be reduced further by inspecting a smaller group of facilities that represent the majority of an agency's CRV and then extrapolating for the remainder of the assets.

This procedure is based on the condition of the plant, and focuses on the system and facility level rather than the component level. It involves a simplified condition code system and parametric estimating to determine an approximation of a facility's BMAR.

Method 3 - This procedure was developed and suggested by Greg Spencer, Chief, Maintenance and Logistics Branch, Dryden Flight Research Center, during the NASA Facilities Maintenance Workshop, February 2000.

This is a condition-based method, which is a simplified version of Method 1. It is a statistical model, which uses real property data (CRV) and is based at the facility level rather than at the equipment level. A facility is divided into three major systems, which are assigned weighted percentages representing their expected impact on overall facility condition, e.g., structural - 40%, mechanical - 30%, and electrical - 30%. The process involves randomly selecting the proper sample size of facilities (based on confidence level desired) and determining each facility's overall net condition. This is done by summing the product of each system's condition code (using standard NASA 5-tiered condition codes) and its weighted percentage. An example for a single facility could be:

System	Condition Code	System Weight
Structural	3	40%

Mechanical	3	30%
Electrical	4	30%

Facility Net Condition Code = (3 x 0.4)+(3 x 0.3)+(4 x 0.3) = 3.3

A Condition Code Factor (CCF) is then determined for each facility. Based on actual data from DFRC, the CCF can be represented by an exponentially decaying function (the CCF approaches zero (exponentially) as the facility net condition code increases from one to five (as shown in Figure 1 below).

This relationship between the CCF and the Net Facility Condition is a reasonable expectation at most locations and could be used as a standard assumption in using this method to approximate the BMAR. The CCF can then be calculated using the formula:

CCF = k1(exp(k2(1 - NC))) where:

CCF = condition code factor
k1 and k2 = constants (value of constants is subject to further study)
exp = "e" or 2.718
NC = the net condition code for the facility

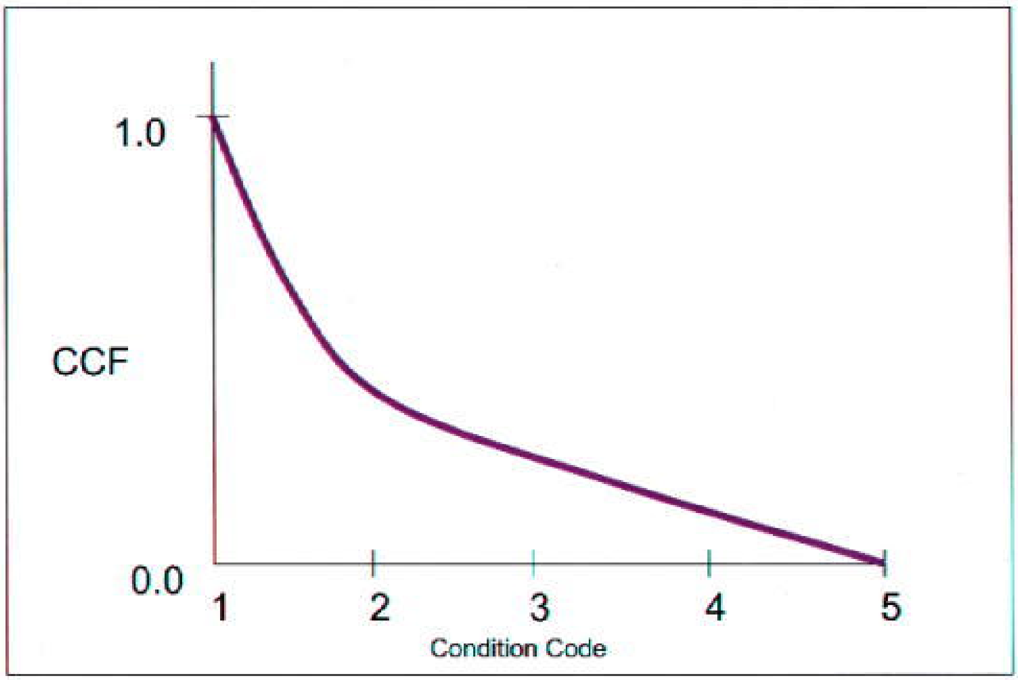

Figure H-2. CCF Relationship to Facility Net Condition

The approximation of the BMAR for the facility involved is then determined by multiplying the CCF by the CRV for the facility. The BMAR for the overall site is determined by averaging the CCF for all facilities selected in the random sample, and multiplying that average CCF by the total CRV for the site.

This process is strictly condition based and is a simplified statistical calculation where lessor degrees of accuracy are acceptable.

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